PRBS Generation and Eye Pattern

**Aim:** To introduce you to the pseudo random binary sequence (PRBS) generator; time domain viewing using two important methods: snap shot and eye patterns. You will also be introduced to a two generator synchronization and alignment. There will also be a comparison of the snap shot display with the eye pattern display. This is a two part experiment.

**Introduction to Part One:** In digital work a binary sequence, with a known pattern of ‘1’ and ‘0’, is common. It is more common to measure bit error rates (BER) than signal-to-noise ratio (SNR), and this is simplified by the fact that known binary sequences are easy to generate and reproduce. A common sequence is the pseudo random binary sequence.

The output from a pseudo random binary sequence generator is a bit stream of binary pulses; i.e., a sequence of 1’s (HI) or 0’s (LO), of a known and reproducible pattern.

The bit rate, or number of bits per second, is determined by the frequency of an external clock, which is used to drive the generator. For each clock period a single bit is emitted from the generator; either at the ‘1’ or ‘0’ level, and of a width equal to the clock period. For this reason the external clock is referred to as a bit clock.

For a long sequence the 1’s and 0’s are distributed in a (pseudo) random manner.

The sequence pattern repeats after a defined number of clock periods. In a typical generator the length of the sequence may be set to $2^n$ clock periods, where $n$ is an integer. In the TIMS SEQUENCE GENERATOR (which provides two, independent sequences, X and Y) the value of $n$ may be switched to one of three values, namely 2, 5, or 11. There are two switch positions for the case $n = 5$, giving different patterns. The SYNCH output provides a reference pulse generated once per sequence repetition period.

One important application of the PRBS is for supplying a known binary sequence. This is used as a test signal (message) when making bit error rate (BER) measurements.

For this purpose a perfect copy of the transmitted sequence is required at the receiver, for direct comparison with the received sequence. This perfect copy is obtained from a second, identical, PRBS generator.
The second generator requires:

1. bit clock information, so that it runs at the same rate as the first

2. a method of aligning its output sequence with the received sequence. Due to transmission through a band-limited channel, it will be delayed in time with respect to the sequence at the transmitter.

**Introduction to Part Two:** It is well known that, when a signal passes via a bandlimited channel it will suffer waveform distortion. As an example, refer to Figure 1. As the data rate increases the waveform distortion increases, until transmission becomes impossible.

![Figure 1: waveforms before and after moderate bandlimiting](image)

In this experiment you will be introduced to some important aspects of pulse transmission which are relevant to digital and data communication applications.
Procedure to Part One:

The Snapshot Display

![Figure 1: Examination of a SEQUENCE GENERATOR](image)

**T1** before inserting the SEQUENCE GENERATOR set the on-board DIP switch SW2 to generate a short sequence (both toggles of the on-board switch SW2 UP)). Then patch up the model of Figure 2 above. Set the AUDIO OSCILLATOR, acting as the bit clock, to about 2 kHz.

**T2** observe the TTL sequence on CH1-A. Try triggering the oscilloscope to the sequence itself (CH1-A). Notice that you may be able to obtain a stable picture, but it may change when the re-set button is pressed (this re-starts the sequence each time from the same point, referred to as the 'start of sequence').

**T3** try triggering off the bit clock. Notice that it is difficult (impossible?) to obtain a stable display of the sequence.

**T4** change the mode of oscilloscope triggering. Instead of using the signal itself, use the start-of-sequence SYNC signal from the SEQUENCE GENERATOR, connected to ‘ext. trig’ of the oscilloscope.

**T5** have a look with your oscilloscope at a yellow analog output from the SEQUENCE GENERATOR. The DC offset has been removed, and the amplitude is now suitable for processing by analog modules (eg., by a filter representing an analog channel). Observe also that the polarity has been reversed with respect to the TTL version. This is just a consequence of the internal circuitry; if not noticed it can cause misunderstandings!
**Band Limiting**

The displays you have seen on the oscilloscope are probably as you would have expected them to be! That is, either ‘HI’ or ‘LO’ with sharp, almost invisible, transitions between them. This implies that there was no band limiting between the signal and the viewing instrument.

If transmitted via a low-pass filter, which could represent a band-limited (base-band) channel, then there will be some modification of the shape, as viewed in the time domain.

For this part of the experiment you will use a TUNEABLE LPF to limit, and vary, the bandwidth. Because the sequence will be going to an analog module it will be necessary to select an ‘analog’ output from the SEQUENCE GENERATOR.

**T6** select a short sequence from the SEQUENCE GENERATOR.

**T7** connect an analog version of the sequence (YELLOW) to the input of a TUNEABLE LPF.

**T8** on the front panel of the TUNEABLE LPF set the toggle switch to the WIDE position. Obtain the widest bandwidth by rotating the TUNE control fully clockwise.

**T9** with the oscilloscope still triggered by the ‘start-of-sequence’ SYNC signal, observe both the filter input and output on separate oscilloscope channels. Adjust the gain control on the TUNEABLE LPF so the amplitudes are approximately equal.

**T10** monitor the filter corner frequency, by measuring the CLK signal from the TUNEABLE LPF with the FREQUENCY COUNTER. Slowly reduce the bandwidth, and compare the difference between the two displays. Notice that, with reducing bandwidth:

a) identification of individual bits becomes more difficult

b) there is an increasing delay between input and output.
Two Generator Alignment

Two SEQUENCE GENERATOR modules may be coupled so that they deliver two identical, *aligned*, sequences.

- that they should deliver the *same sequence* it is sufficient that the generator circuitry be identical
- that they be at the *same rate* it is necessary that they share a common bit clock
- that they be *aligned* requires that they start at the same time.

TIMS SEQUENCE GENERATOR modules (and those available commercially) have inbuilt facilities to simplify the alignment operation. One method will be examined with the scheme illustrated in block diagram form in Figure 2 below.

![Figure 2: aligning two identical generators](image)

**T11** before plugging in the SEQUENCE GENERATOR modules, set them both to the same short sequence.

**T12** patch together as above, but omit the link from the ‘GENERATOR #1’ SYNC to ‘GENERATOR #2’ RESET. Do not forget to connect the ‘start-of-sequence’ SYNC signal of the GENERATOR #1 to the ‘ext. trig’ of the oscilloscope.
**T13** press the ‘GENERATOR #2’ RESET push button several times. Observe on the oscilloscope that the two output sequences are synchronized in time but the data bits do not line-up correctly. Try to synchronize the sequences manually by repeating this exercise many times. It is a hit-and-miss operation, and is likely to be successful only irregularly.

**T14** connect the SYNC of the ‘GENERATOR #1’ to the RESET of the ‘GENERATOR #2’. Observe on the oscilloscope that the two output sequences are now synchronized in time and their data are **aligned**.

**T15** break the synchronizing path between the two generators. What happens to the alignment? *(This is an important observation to make. Please take this as one of the discussion question).*

The above scheme has demonstrated a method of aligning two generators, and was seen to perform satisfactorily. But it was in a somewhat over simplified environment.

What if the two generators had been separated some distance, with the result that there was a delay between sending the SYNC pulse from GENERATOR #1 and its reception at GENERATOR #2?

*The sequences would be offset by the time delay*

In other words, the sequences would *not* be aligned.
Procedure to Part Two:

T1 set up the model of Figure 2. The AUDIO OSCILLATOR serves as the bit clock for the SEQUENCE GENERATOR. A convenient rate to start with is 2 kHz. Select CHANNEL #1. Select a short sequence (both toggles of the on-board switch SW2 UP)

![Figure 2: viewing snap shots and eye patterns](image)

T2 synchronize the oscilloscope to the 'start-of-sequence' synchronizing signal from the SEQUENCE GENERATOR. This is the 'snap shot' mode. Both traces should be displaying the same picture, since CHANNEL #1 is a 'straight through' connection.

The remaining three channels (#2, #3, and #4) in the BASEBAND CHANNEL FILTERS module represent channels having the same slot bandwidth (40 dB stopband attenuation at 4 kHz), but otherwise different transmission characteristics, and, in particular, different 3 dB frequencies.

You should also prepare a TUNEABLE LPF to use as a fourth channel, giving it a 40 dB attenuation at 4 kHz. To do this:
**T3 using a sinusoidal output from an AUDIO OSCILLATOR as a test input:**

- **a)** set the TUNE and GAIN controls of the TUNEABLE LPF fully clockwise. Select the NORM bandwidth mode.
- **b)** set the AUDIO OSCILLATOR to a frequency of, say, 1 kHz. This is well within the current filter passband.
- **c)** note the output amplitude on the oscilloscope.
- **d)** increase the frequency of the AUDIO OSCILLATOR to 4 kHz.
- **e)** reduce the bandwidth of the TUNEABLE LPF (rotate the TUNE control anti-clockwise) until the output amplitude falls 100 times. This is a 40 dB reduction relative to the passband gain.

**Snap-shot assessment**

Now it is your task to make an assessment of the maximum rate, controlled by the frequency of the AUDIO OSCILLATOR, at which a sequence of pulses can be transmitted through each filter before they suffer unacceptable distortion. The criterion for judging the maximum possible pulse rate will be your opinion that you can recognize the output sequence as being similar to that at the input.

It is important to remember that the four filters have the same slot bandwidth (ie., 4 kHz, where the attenuation is 40 dB) but different 3 dB bandwidths.

To relate the situation to a practical communication system you should consider the filters to represent the total of all the filtering effects at various stages of the transmission chain, ie., transmitter, channel, and the receiver right up to the input of the decision device.

**Eye Pattern Assessment**

Now you will repeat the previous exercise, but, instead of observing the sequence as a single trace, you will use eye patterns. The set-up will remain the same except for the oscilloscope usage and sequence length.

So far you have used a short sequence, since this was convenient for the snapshot display. But for eye pattern displays a longer sequence is preferable, since this generates a greater number of patterns.
**T4** change the oscilloscope synchronizing signal from the *start-of-sequence* SYNC output of the SEQUENCE GENERATOR to the sequence *bit clock*. Increase the sequence length (both toggles of the on-board switch SW2 DOWN). Make sure the oscilloscope is set to pass DC.

**T5** select CHANNEL #2. Use a data rate of about 2 kHz. You should have a display on CH2-A similar to that of Figure 3 below.

![Figure 3: a ‘good’ eye pattern](image)

**T6** increase the data rate until the eye starts to close. Figure 4 shows an eye not nearly as clearly defined as that of Figure 3.

![Figure 4: compare with Figure 3; a faster date rate](image)

**T7** take some time to examine the display, and consider what it is you are looking at! There is one ‘eye’ per bit period. Those shown in Figure 3 are considered to be ‘wide open’. But as the data rate increases the eye begins to close.
The actual shape of an eye is determined (in a linear system) primarily by the filter (channel) amplitude and phase characteristics (for a given input waveform).

The detector must make a decision, at an appropriate moment in the bit period, as to whether or not the signal is above or below a certain voltage level. If above it decides the current bit is a HI, otherwise a LO.

Questions:

1) was there any obvious misalignment between the TTL sequence input to, and the bandlimited sequence output from, the TUNEABLE LPF? Explain.

2) Explain GIBBS Phenomena and its significance.